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(54) Synchronous digital telecommunications transmission system, control device, network element, and central clock generator

(57) The network elements NE1, ..., NE6 of a digital synchronous telecommunications transmission system must be synchronized to each other without it being possible for clock loops to arise in the process.

A network node NODE contains network elements NE1, ..., NE6 and a central clock generator SASE. The network elements send clock signals 2M to the clock generator which contain a clock of a telecommunications signal STM-N and a quality indicator (SSM) contained in the telecommunications signal which indicates the quality of the clock. The clock generator selects one of the clock signals 2M as reference clock REF and communicates to a control device STE concerning which of the clock signals it selected and how high the accuracy of this clock signal is. On the basis of this communication, the control device gives the network elements instructions ANW concerning the quality indicator which the network elements should send at their outputs.

Figure 1

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Description

The invention concerns a synchronous digital telecommunications transmission system, a control device for a network node of a synchronous digital telecommunications transmission system, a network element and a central clock generator for a network node of a synchronous digital telecommunications transmission system.

A synchronous digital telecommunications transmission system by way of example is an SDH system or SONET system (SHD = synchronous digital hierarchy, SONET = synchronous optical network). In the transmission of messages in such telecommunications transmission systems, it is essentially important that all network elements (for example add/drop multiplexers, crossconnects, or power multiplexers) work synchronously with each other. The ITU recommendation G 803 furthermore specifies that a network node which contains several network elements must be supplied with a reference clock by a single central clock generator of the network node.

A conference article by Dr. M. Wolf, 8th European Frequency and Time Forum, March 9-11, 1994, Technological University of Munich, pages 166 through 174, describes how in a network node, the synchronization of the network elements of such a synchronous digital telecommunications transmission system can take place: A network element receives at two inputs message signals from which a clock is derived which can be used for the synchronization. The accuracy of the clocks of these message signals is indicated by a quality indicator contained therein, which will be referred to below as SSM (synchronization status message; see, for example, ITU-T recommendations G 707, G 708, or G 709). A selector device in the network element selects one of the clocks as reference clock on the basis of the SSM and relays it to a central clock generator of the network node. This central clock generator distributes the reference

clock to all network elements of the network node. It is also described that the central clock generator can be a self-contained unit or that the clock generator of a network element, preferably that of a crossconnect can be used as central clock generator. In order to prevent the formation of synchronization loops, i.e., to prevent two network elements from using each other as reference source, a supplemental SSM is defined: "Do not use for synchronization," referred to below as DNU. This should be transmitted by a network element to all outputs which are connected to the network element which is selected as reference clock source.

A problem which is connected with the solution described is that the network elements of the network node do not recognize the source of the selected reference clock nor its accuracy. Also the central clock generator cannot provide this information since a selection of the clock takes place in the selector device of a network element. As the accuracy of their reference clock, network elements thus can only indicate the accuracy of the central clock generator in free, unsynchronized operation, which as a rule corresponds to the accuracy established in ITU-T G 812. In addition, the SSM DNU cannot be sent to the outputs which are connected to reference source used for synchronization since this reference source is not known to the network elements. This can result in the formation of synchronization loops.

The task of the invention is to suggest a synchronous digital telecommunications transmission system for which the transmission of a quality indicator (SSM) corresponding to the accuracy of the reference clock used in a network node is made possible. Another task of the invention is to suggest a control device for a network node of such a telecommunications transmission system. Further tasks of the invention are to suggest a network element and a central clock generator for such a telecommunications transmission system.

The task is solved with respect to the telecommunications transmission system through the features of Patent Claim 1, with respect to the control device through the features of Patent Claim 2, with respect to the network element through the features of Patent Claim 6, and with respect to the central clock generator through the features of Patent Claim 8. Advantageous configurations can be found in the dependent claims.

An advantage of the invention is that the formation of synchronization loops is avoided in a synchronous digital telecommunications transmission system in accordance with the invention.

The invention will be explained in the following exemplary embodiments with the aid of Figures 1 through 4.

Figure 1	shows a control device and a network node of several network elements and a central clock generator,
Figure 2	shows the network node from Figure 1 and a two-part control device,
Figure 3	shows a network element which is connected to a central clock generator, and
Figure 4	shows three network nodes and a central control device.

Network elements in a synchronous digital telecommunications transmission system work synchronously with each other by matching their own clock pulse generator to a clock derived from a received telecommunications signal. Since network elements receive telecommunications signals at several inputs, a selection takes place between the several received telecommunications signals as to which clock the internal clock pulse generator is matched, i.e., which clock is used as reference clock. A quality indicator transmitted in each telecommunications signal, such as is established, for example, in ITU-T recommendation G 707 serves for the selection. This quality

indicator indicates the accuracy of the clock of the particular telecommunications signal and is designated below as SSM (synchronization status message).

According to the invention, the selection of a reference clock takes place in a central clock generator, the function of which is to supply all network elements of a network node with a central reference clock. Another important point of the invention is that the central clock generator sends a message to a control device concerning its synchronization condition. The message contains the accuracy of the clock selected as reference clock and the source of this clock. The control device in turn sends instructions to all network elements of the network node as to which quality indicator they must communicate at which output.

In a first exemplary embodiment depicted in Figure 1, a synchronous digital telecommunications transmission system contains a network node NODE and a control device STE. Network node NODE contains six network elements NE1, ..., NE6 which are connected to other not-depicted network elements of the synchronous digital telecommunications transmission system and send and receive telecommunications signals STM-N. In Figure 1, this is suggested for each network element through two double arrows. This does not mean, however, that the six network elements NE1, ..., NE6 are each connected to two other network elements, but rather it suggests that each of the six network elements NE1, ..., NE6 receives and sends telecommunications signals from and to one or more of the other, not-depicted network elements.

The six network elements NE1, ..., NE6 are connected to a central clock generator SASE and receive from it a reference clock REF to which each network element NE1, ..., NE6 of network node NODE matches its clock pulse generator. Network elements NE1, ..., NE6 as a result work synchronously with each other. Central clock generator SASE in turn is connected to clock signal outputs of two of network elements NE1, NE4 and receives from them clock signals 2M. Such a

clock signal 2M contains a clock which the sending network element NE1, NE4 derived from a received telecommunications signal STM-N and in addition a quality indicator which indicates the accuracy of the clock in which telecommunications signal STM-N is contained.

In the first exemplary embodiment the clock signal is a signal with a transmission rate of 2 MBit/s and the clock is a clock with a pulse repetition rate of 2 MHz which is derived from a telecommunications signal STM-N of the synchronous digital hierarchy (SDH). In the clock signal, the quality indicator (SSM) is transmitted which according to ITU-T recommendation G 707 is contained in the framework of received telecommunications signal STM-N.

Central clock generator SASE selects one of clock signals 2M on the basis of the quality indicators, derives a clock from selected clock signal 2M, and matches its own internal clock pulse generator to this clock. This internal clock pulse generator represents the reference clock source of network node NODE, and the reference clock for network elements NE1, ..., NE6 is taken from it. In the event of a disturbance, for example upon loss of certain telecommunications signals from which the clock signals are derived, the clock pulse generator of the central clock generator continues to run in free unsynchronized operation and continues to supply a reference clock REF for network node NODE. The accuracy of the reference clock in free, unsynchronized operation then corresponds to the accuracy of the clock pulse generator which in the exemplary embodiment is the accuracy established in ITU-T G 812.

Control device STE in the first exemplary embodiment is connected to central clock generator SASE and receives from it a message STAT concerning its synchronization condition. The content of this message is the accuracy of the selected clock according to the associated SSM and the source of the clock, i.e., from which network element of the selected clock signal is received and to which of the clock signal inputs the clock signal is applied. In the first exemplary

embodiment, the connection between central clock generator SASE and control device STE uses an X 25 interface.

Message STAT is sent by central clock generator SASE always when the latter, for example because of a loss of the selected clock signal, selects another clock signal for matching its clock pulse generator. The conveying of this message to the control device is not time critical, since a change in the accuracy of reference clock REF does not have an effect on the synchronous digital telecommunications transmission system until after a relatively long period of time of several hours or days. This is due to the specified high accuracy of the received clocks and the high accuracy of the clock pulse generator in free, unsynchronized operation which are established by way of example for SDH in ITU-T recommendations G 811, G 812, and G 813. An effect on the synchronous digital telecommunications transmission system could be, by way of example, an increase in the slip rate.

Control device STE has a connection to individual network elements NE1, ..., NE6 over which it transmits instructions ANW to network elements NE1, ..., NE6. In Figure 1 this is depicted through a dark line, which does not mean, however, that it is a parallel connection through which all network elements receive the same instruction, but rather each network element receives one or more instructions of its own. This information can be transmitted through the existing Q interfaces of the network management which are established in ITU-T recommendations Q 811 and Q 812. Instructions ANW concern the SSM which network elements NE1, ..., NE6 are to transmit at their individual outputs in telecommunications signals STM-N which are to be sent at such outputs.

Figure 2 shows a second exemplary embodiment of a control device STE. The depicted network node NODE is the same network NODE as in Figure 1. Control device STE in this second

exemplary embodiment comprises two separate units: a first control unit SSU-M which is connected to central clock generator SASE and a second control unit SDH-M which is connected to network elements NE1, ..., NE6. The two control units are connected to each other through a transmission medium Q. Advantageously this is a Q interface. First control unit SSU-M is a control unit for controlling and monitoring a number of central clock generators of different network nodes. The second control device controls and monitors network elements of the synchronous digital transmission system.

One of the network elements NE1 and central clock generator SASE from the first of the two exemplary embodiments is depicted in detail in Figure 3. The network element in this example has four terminals IO1, ..., IO4 at which telecommunications signals STM-N from other, not-depicted network elements are received and to which they are sent. Assigned to two of terminals IO1, IO2 is one clock deriving circuit TA each, out of which a clock is derived from received telecommunications signals STM-N. In addition, the SSM of received telecommunications signal STM-N is read at the two terminals IO1, IO2. Using the derived clock, a clock signal 2M is generated which contains the SSM. These clock signals 2M can be accessed at two clock signal outputs O1, O2.

Network element NE1 in addition has a reference clock input at which a reference clock REF is received from central clock generator SASE. Reference clock REF is fed to a clock pulse generator SEC of network element NE1 in order to match it to reference clock REF. At an additional input A1, network element NE1 can receive instructions ANW from a control device. The instructions concern which SSMs should be sent in telecommunications signals STM-N from the individual terminals.

In the exemplary embodiment, the central clock generator has six clock signal inputs I1, ..., I6 at which clock signals 2M are received from network elements. In the depicted example, two clock signal inputs I1, I2 are connected to two clock signal outputs O1, O2 of network element NE1. The remaining clock signal inputs can be connected to clock signal outputs of other network elements of the node. Clock signal inputs I1, ..., I6 are connected to a selector device SEL. This device evaluates the SSMs contained in the clock signals and selects on the basis of the SSMs the clock signal with the most accurate clock. If several clock signals have the same clock quality, there can either be a preset sequence for selection so that the clock signal of a certain clock signal input will be preferred in the event of equal quality, or an arbitrary selection can be made.

A clock is derived from the selected clock signal and is fed to a clock pulse generator GEN of central clock generator SASE in order to match it. Clock pulse generator GEN delivers reference clock REF for all network elements of the node and is connected to a reference clock output CO at which a reference clock can be accessed. This reference clock output CO is connected to reference clock input CI of network element NE1.

A synchronous digital telecommunications transmission system of a third exemplary embodiment, depicted in Figure 3, contains three network nodes NODE1, NODE2, NODE3 which are connected to each other and a control device STE. Each of the three network nodes comprises three network elements NE11, ..., NE13, ..., NE31, ..., NE33 and a central clock generator SASE 1, ..., SASE 3. The number of network elements in a network node, however, is not restricted to three. The network elements of a network node receive a reference clock REF from the central clock generator of the network node over reference clock lines. The central clock generator receives clock signals 2M from the network elements. From the connections over which the central clock generators receive the clock signals, only those are drawn in which the particular central clock generator has selected for matching with its clock pulse generator.

Central clock generators SASE 1, ..., SASE3 are connected to control device STE and transmit to it messages STAT concerning their synchronization condition. On the basis of these messages, the control device sends instructions ANW to the individual network elements NE11, ..., NE13, ..., NE31, ..., NE33 as to which SSM they should send at their individual outputs. In the exemplary embodiment, central clock generator SASE 3 of third network node NODE3 has selected a clock signal 2M of network element NE32 for synchronization of its clock pulse generator. The clock contained therein originates from a not-depicted source to which network element NE32 is connected through telecommunications connections STM-N and has the accuracy established in ITU-T recommendation G 811. Central clock generator SASE3 informs control device STE that it has selected the clock signal of network element NE32 for the reference clock, and that this clock has the accuracy of G 811. The central control then provides to the network elements instructions ANW as to which SSMs they must send to their outputs. the SSMs which the network elements send to their outputs are listed in Table 1.

Table 1

SSM which is sent from the individual network elements to the different outputs		
from:	to:	SSM
NE11	NE21	DNU
NE21	NE11	G 811
NE11	NE22	DNU
NE22	NE11	G 811
NE12	NE23	DNU
NE23	NE12	G 811
NE13	NE31	DNU
NE31	NE13	G 811
NE31	NE23	G 811
NE23	NE31	DNU

The reference clock of third network node NODE3 has the accuracy of G 811. Network elements NE31, ..., NE33 of the third network node therefore send the code G 811 in the SSM. Network

element NE23 of the second network node receives from network element NE31 a telecommunications signal with said clock quality, derives from it a clock signal, and passes it on to the central clock generator SASE2 of the second network node. This node selects the clock signal as reference clock for second network node NODE2 and distributes the clock to connected network elements NE21, ..., NE23. The message to the control unit contains the information that the telecommunications signal used for synchronization of the node originates from a certain input of network element NE23 and that the accuracy of the clock is G 811. The control device now informs network element NE23 that it should send the SSM DNU ("do not use for synchronization") to network element NE31, but should send the SSM G 811 to network element NE12. Network elements NE22 and NE21 are likewise instructed to send the SSM G 811.

Network element NE11 of first network node NODE1 receives from each of network element NE21 and network element 22 a telecommunications signal which contains the SSM G 811. From each of these telecommunications signals, it derives a clock signal for central clock generator SASE1 of first network node NODE1. Central clock generator SASE1 selects one of these clock signals and informs control device STE of the selection and the accuracy of the selected clock signal. Control device STE instructs network elements NE11 and NE12 to send the SSM DNU in the direction of the second network node. In like manner, network element NE13 must send the SSM DNU to network element NE31 of third network node NODE3 so that no clock loop can arise as a result of clock generator SASE3 of third network node NODE3 selecting, for purposes of matching its clock pulse generator, a clock signal which contains the clock of the network signal received from network element NE13.

Control device STE determines the instructions ANW on the basis of messages STAT. For this purpose, predetermined tables, by way of example, can be contained in a memory of the control device which contains the instructions for the individual network elements for every possible

combination of messages of the connected clock generators. Another possibility consists of the central control having information concerning the configuration of the connected network nodes, i.e., what connections exist between the network nodes and to which inputs of the central clock generators a clock signal which is derived from telecommunications signals received over these connections is applied. With the aid of this information, the central control can determine which SSM must be sent from the individual network elements.

Patent Claims

1. Synchronous digital telecommunications transmission system with at least one network node (NODE; NODE1, ..., NODE3) which contains network elements (NE1, ..., NE6; NE11, ..., NE13, NE21, ..., NE33) and a central clock generator (SASE; SASE1, ..., SASE3), and with at least one control device (STE) in which

   - the network elements are connected to the central clock generator and receive through this connection a reference clock (REF) from the central clock generator,
   - the central clock generator is connected to at least a portion of the network elements (NE1, NE4, NE11, NE23, NE32) and through these connections receives in total at least two clock signals (2M) each of which contains a clock and a quality indicator which indicates the accuracy of the clock, the central clock generator is connected to the control unit (STE) and through this connection transmits messages (STAT) concerning its synchronization condition to the control device, and in which
   - the control device (STE) is connected to the network elements and through these connections transmits instructions (ANW) to the network elements with the instructions indicating the quality indicators to send to the network elements.

2. Control device (STE) for a network node (NODE; NODE1, …, NODE3), which contains several network elements (NE1, …, NE6, NE11, …, NE13, NE21, …, NE33) and a central clock generator (SASE; SASE1, …, SASE3), of a synchronous digital telecommunications transmission system of several network elements, characterized by

- means for receiving a message (STAT) concerning the synchronization condition of the central clock generator and
- means for transmitting instructions (ANW) to the network elements, with the instructions indicating to the network elements which should be sent from the network elements and which[1] serves for selection of an external reference clock for network elements which do not belong to the network node.

3. Control device (STE) according to Claim 2 which is provided for the control of several network nodes.

4. Control device (STE) according to Claim 2 which comprises a first control unit (SSU-M) and a second control unit (SDH-M) which are connected to each other through a transmission medium (Q).

5. Control device (STE) according to Claim 2 in which the means for transmitting instructions (ANW) to the network elements (NE1, ..., NE6) are means for transmitting information over a Q interface.

6. Network element (NE1) with a clock pulse generator (SEC) which can be matched to a reference clock (REF), a reference clock input (CI) which is connected to the clock pulse

generator (SEC) for receiving the reference clock (REF), and a number of terminals (IO1, ..., IO4) for receiving and sending telecommunications signals (STM-N), with there being assigned to each of at least a portion of the terminals (1O1, 1O2)[2] a clock-deriving circuit (TA) for deriving a clock from the telecommunications signal (STM-N) which is received at the associated terminal

characterized through

- clock signal outputs (O1, O2) each of which are assigned to one of the terminals (IO1, IO2) with clock deriving circuit (TA), for transmission of clock signals (2M) which contain the message signal (STM-N received in the associated terminal and a quality indicator which indicates the accuracy of the clock and
- an input (AI) for receiving instructions (ANW), with the instructions indicating to the network element (NE1) quality indicators which are to be sent from the network element (NE1) to the individual terminals (IO1, ..., IO4).

7. Network element (NE1) according to Claim 6 characterized in that the clock signal outputs (O1, O2) are a 2-Mbit interface, that the reference clock input (C1) is a 2 MHz interface, and that the input (A1) for receiving instructions (ANW) is a Q interface.

8. Central clock generator (SASE, SASE1, ..., SASE3) for a network node (NODE; NODE1, ..., NODE3) of a synchronous digital telecommunications transmission system with a clock pulse generator (GEN) which is matched to an external clock and a reference clock output (CO) at which a reference clock (REF) for network elements (NE1, ..., NE6, NE11, ..., NE13, NE21, ..., NE33) of the network node can be accessed,

characterized by

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[1] Translator's note: there is a wrong gender or a wrong case in the German for this expression.
[2] Translator's note: sic in the German

- a number of clock signal inputs (I1, ..., I6) for receiving clock signals (2M) each of which contain a clock and a quality indicator which indicates the accuracy of the clock
- a selector device for selecting the external clock for matching the clock pulse generator GEN with the aid of quality indicators,
- an output for transmission of a message (STAT) concerning the synchronization condition of the central clock generator (SASE) to a control device (STE).

9. Central clock generator according to Claim 8 characterized in that the clock signal inputs are 2 MBit interfaces and that the output for transmitting a message (STAT) is an X 25 interface.